

TOPIC E –

ENVIRO CHEMISTRY

PART 11 – FURTHER

ACID DEPOSITION HL

IB Chemistry

Topic E – Enviro

Hodder Ed - Talbot



E11 Acid deposition - 1 hour

- E.11.1 Describe the mechanism of acid deposition caused by the oxides of nitrogen and oxides of sulfur. (2)
- E.11.2 Explain the role of ammonia in acid deposition. (3)



E11 E11.1 – Acid Deposition by NO and SO_x

- E.11.1 **Describe** the mechanism of acid deposition caused by the oxides of nitrogen and oxides of sulfur. (2)
- *Formation of hydroxyl radicals:*
 - $H_2O + O_3 \rightarrow 2HO\bullet + O_2$
 - *OR...* $H_2O + O\bullet \rightarrow 2HO\bullet$
 - $HO\bullet + NO_2 \rightarrow HNO_3$
 - $HO\bullet + NO \rightarrow HNO_2$
 - $HO\bullet + SO_2 \rightarrow HOSO_2\bullet$
 - $HOSO_2\bullet + O_2 \rightarrow HO_2\bullet + SO_3$
 - $(SO_3 + H_2O \rightarrow H_2SO_4)$



E11.1 – Creating OH•

- As discussed earlier
 - $\text{O}^{\bullet*} + \text{H}_2\text{O} \rightarrow 2\text{HO}^{\bullet}$
- The HO^{\bullet} is also formed by:
 - $\text{O}_3 + \text{H}_2\text{O} \rightarrow 2\text{HO}^{\bullet} + \text{O}_2$
- Aside from their role in formation of photochemical smog, the HO^{\bullet} are important in the formation of nitric, nitrous, and sulfuric acid in the atmosphere



E11.1 – Formation of N Acids

- $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$ (from combustion of fuel)
- Formation of Nitrous Acid (HNO_2)
 - $\text{HO}\bullet + \text{NO}\bullet \rightarrow \text{HNO}_2$
 - Moderately soluble in water, so HNO_2 dissociates
 - ◆ $\text{HNO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NO}_2^-$ (weak acid dissociates)
 - ◆ $\text{HNO}_2 (+\text{UV}) \rightarrow \text{HO}\bullet + \text{NO}$ (photolyzed back to NO, HO)
- Formation of Nitric Acid (HNO_3)
 - $2\text{NO}\bullet + \text{O}_2 \rightarrow 2\text{NO}_2\bullet$
 - $\text{HO}\bullet + \bullet\text{NO}_2 \rightarrow \text{HNO}_3$
 - Strong Acid = more soluble in water
 - ◆ $\text{HNO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{NO}_3^-$ (100% dissociation)



E11.1 – Formation of Sulfurous Acid

- $S + O_2 \rightarrow SO_2$
- $SO_2 + H_2O \rightarrow H_2SO_3$ (dissolves and reacts in water)
 - H_2SO_3 is considered a weak acid
 - $H_2SO_3 + H_2O \rightleftharpoons HSO_3^- + H_3O^+ \quad pK_a = 1.85$
 - $HSO_3^- + H_2O \rightleftharpoons SO_3^{2-} + H_3O^+ \quad pK_a = 7.20$



E11.1 – Formation of Sulfuric Acid

- $S + O_2 \rightarrow SO_2$
- $HO\bullet + SO_2 \rightarrow HOSO_2\bullet$
- $HOSO_2\bullet + O_2 \rightarrow HO_2\bullet + SO_3$
- $SO_3 + H_2O \rightarrow H_2SO_4$
- Sulfuric Acid formation in clouds:
 - ◆ $O_3 + SO_2 + H_2O \rightarrow HSO_4^- + H^+ + O_2$
 - ◆ $O_3 + HSO_3^- \rightarrow HSO_4^- + O_2$
 - ◆ $O_3 + SO_3^{2-} \rightarrow SO_4^{2-} + O_2$
- Important source for nuclei (seeds) in cloud forming
 - ◆ $H_2O_2 + HSO_3^- \rightarrow HSO_4^- + H_2O$
 - ◆ $CH_3OOH + HSO_3^- \rightarrow HSO_4^- + CH_3OH$



E11.2 - Ammonia

- E.11.2 **Explain** the role of ammonia in acid deposition. (3)
- *In the atmosphere, ammonia neutralizes the acids formed to a large extent, to form ammonium salts. Slightly acidic ammonium salts, $(\text{NH}_4)_2\text{SO}_4$ and NH_4NO_3 , formed in the atmosphere sink to the ground or are washed out of the atmosphere with rain. As NH_4^+ is deposited and enters the soil, nitrification and acidification can occur.*
- $\text{NH}_4^+ + 2\text{O}_2 \rightarrow 2\text{H}^+ + \text{NO}_3^- + \text{H}_2\text{O}$



E12.1 – Origin of Ammonia

- The original source of the earth's atmosphere was ammonia released by volcanoes as the planet cooled.
- The ammonia was eventually photolyzed to form N_2 and only a trace amount of NH_3 exists anymore
- Sources of ammonia in the atmosphere:
 - Decomposition of nitrogenous matter like plants and animal proteins
 - Decomposition of NH_3 -based fertilizers
 - Leakage of NH_3 from refrigerant systems
 - Leakage of NH_3 from manufacturing plants



E11.2 – Ammonium Salts

- Ammonia in the atmosphere can neutralize acid raindrops, forming ammonium salts
 - $2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$
 - $\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$
- They exist in both aqueous and solid forms.
- These salts (formed in atmosphere) are carried to the ground by rain, where they cause damage to plants
- Their particles also form an aerosol haze in the atmosphere decreasing visibility



E11.2 – Nitrification of Soil

- Nitrogen in soil as:
 - Ammonium ions, NH_4^+
 - ◆ Positively charged and attracted to soil particles and retained by the soil
 - Nitrate ions, NO_3^-
 - ◆ Leached out of soil by rain water as fully soluble ions
- NH_4^+ fertilizers are added to soil and slowly they are oxidized to form NO_3^- ions.
- The NH_4^+ ions are oxidized first by a bacterium called ***nitrosomonas***, then by a second called a ***nitrobacter*** (names sound lame, but they are true)



E11.2 – Formation of Nitrite and Nitrate

- First stage, driven by *nitrosomonas*:
 - $\text{NH}_4^+(\text{aq}) + 1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}_2^-(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{H}_2\text{O}(\text{aq})$
- Second stage, driven by *nitrobacter*:
 - $\text{NO}_2^-(\text{aq}) + 1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}_3^-(\text{aq})$
- Together the reactions are:
 - $\text{NH}_4^+(\text{aq}) + 2\text{O}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + \text{H}_2\text{O}(\text{aq}) + \text{NO}_3^-(\text{aq})$
- The addition of NH_4^+ to soil therefore lowers the pH of the soil as **H^+ ions** are produced
- The Ammonia pollution, along with ammonium salts (from rain) leads to **acidification**



E11.2 – The Nitrogen Cycle

